A DATA MANIPULATION SYSTEM FOR FARNSWORTH-MUNSELL 100-HUE TEST RESULTS

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ERB-948
NRCC No. 20771

NOVEMBER 1982

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ABSTRACT

This document describes a microcomputer system used for data manipulation of results derived from the Farnsworth-Munsell 100-hue colour vision test. Its capabilities include database creation and maintenance, data enhancement, and polar graphic output. The system is an example of appropriate technology being applied to the enhancement of a standard test administered by personnel with clinical experience but with minimal computer expertise. It is one link in a broader project to create and analyse several related databases.

RÉSUMÉ

Le présent document décrit un système de traitement sur micro-ordinateur des résultats du test de vision des couleurs 100-hue de Farnsworth-Munsell. Ce système permet la mise en place et l'entretien d'une base de données, l'amélioration des données et une sortie graphique polaire. C'est un exemple de technologie appropriée appliquée à l'amélioration d'un test standard administré par des personnes ayant une expérience médical mais peu de connaissances dans le domaine des ordinateurs. Ce système constitue un maillon d'un plus vaste projet de création et d'analyse de plusieurs bases de données connexes.

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D. Crabtree, H.T.J. Mount,[1] and B.W. Tansley[2]

OVERVIEW OF THE FARNSWORTH-MUNSELL 100-HUE TEST

Since Farnsworth's article was published in 1943 (1), clinicians have generally adopted the 100-hue test, with some minor variations, for examining colour discrimination. The test is based on a more elaborate protocol in which a subject matches colours experimentally and the resulting data are plotted in a chromaticity plane. Analysing results from normal subjects, Farnsworth discovered that 85 of the set of 100 Munsell colours yielded chromaticity data that lay particularly close to a circle in this plane. The centre of the circle depends on the light source used to illuminate the colour references. Using these 85 colours in tests on a colour-anomalous subject yields an approximately elliptic shape in the chromaticity plane. The angular displacement of the major axis characterizes the colour discrimination problem of the subject. This may be, for instance, one of the congenitally colour-anomalous states or, perhaps, one of the multitude of acquired colour vision defects.

Farnsworth claimed that his simpler, more rapid test yields a line of best fit with the same angular displacement as the minor axis of the ellipse in the chromaticity plane. Similarly, then, this line may be used to characterize the subject's colour anomaly. Farnsworth devised a special polar grid (Fig. 1) in which 85 radii have angular displacements equal to those of the 85 data points for normal subjects around the centre of the circle in the chromaticity plane. In turn, these radii correspond to the 85 chosen colour references and are graduated counterclockwise from 1 to 85. The grid has concentric circles at uniform radial increments, the innermost having a graduation of 2, this being the minimum value possible for samples in an error series. The remaining circles are graduated incrementally in unit steps, 3, 4, 5, etc.

The 85 colour references are numbered on their reverse sides serially from 1 to 85 according to their counterclockwise position around a circle or ellipse in the chromaticity plane. They are mounted in black plastic bezels and distributed between four boxes in groups of 22, 21, 21, and 21. References or "caps" 85 and 1 to 21 cover the range from pink to yellow, 22 to 42 yellow to green, 43 to 63 green to purple, and 64 to 84 purple to red. Fixed "pilot" caps at either end of each box have the

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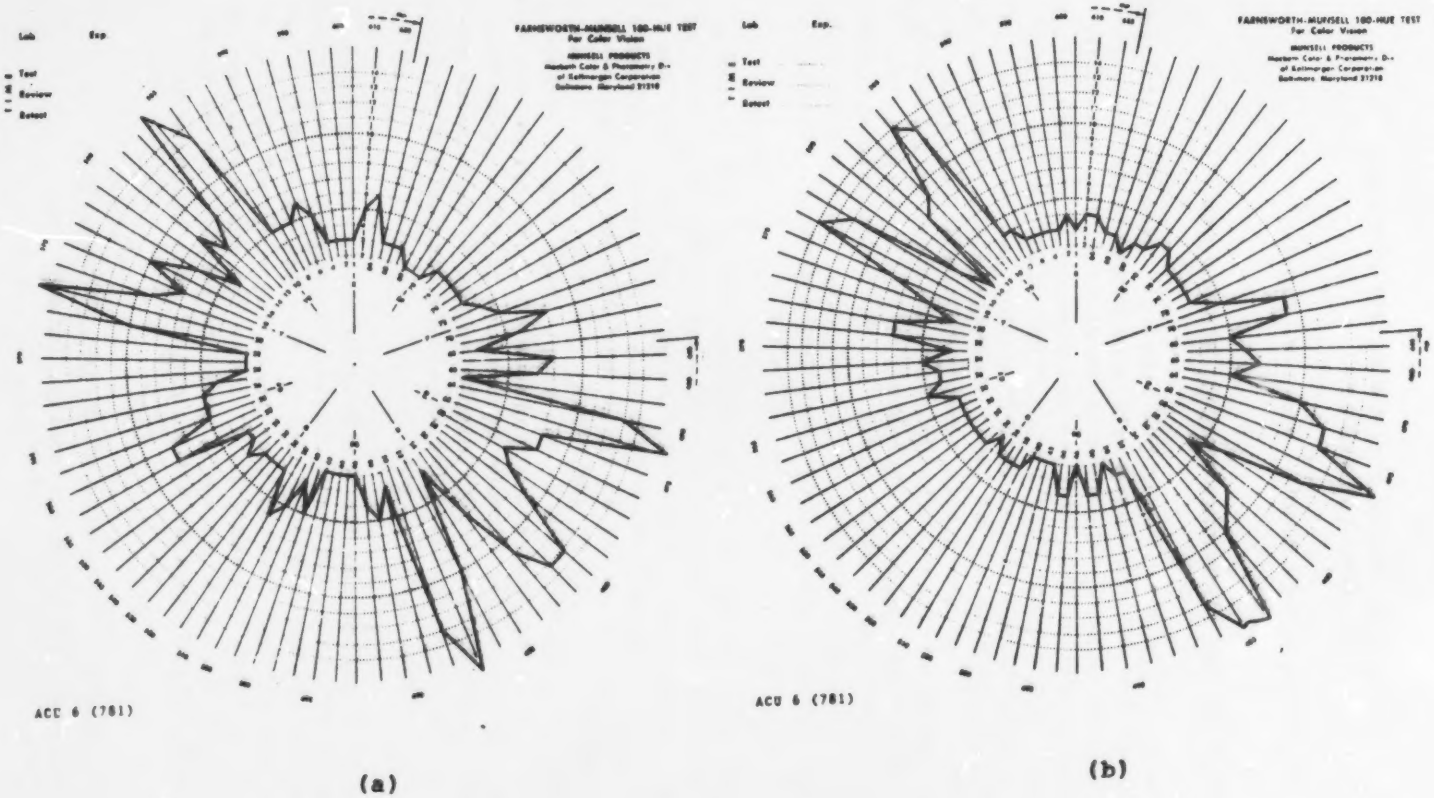

Fig. 1 Farnsworth's polar grid. These Farnsworth-Munsell 100-hue plots are of the (a) right and (b) left eyes in the same patient. They are suggestive of congenital stationary deuteranomaly but compatible with a cone dystrophy or optic neuropathy.

correct hues for those positions. Boxes are presented to the subject separately with the movable caps in random order. Viewing the caps under standard lighting conditions, the subject is asked to rearrange them in correct colour sequence between the two fixed end caps. Thus, while transposition of caps between boxes is prevented, any arrangement within a box is permissible.

According to Kinnear's protocol (2), the error score S(n) is computed from the cap numbers C(n) located at each of the 85 positions n by

$$S(n) = |C(n) - C(n-1)| + |C(n+1) - C(n)|$$

Thus if the three adjacent caps are in correct order, S(n) has the minimum value, 2. These scores comprise an error series which is plotted on the polar grid. With this scoring procedure, any reversals of the caps result in higher values, which plot further from the origin of the polar graph. Therefore, in those regions of colour space in which persons with particular color-vision defects have reduced hue discrimination, a greater number of reversals will occur, resulting in higher error scores. The plot of these error scores will show a pattern of almost diametrically opposed peaks, the axis of which is characteristic of a particular type of colour-vision anomaly. This axis or line of best fit is usually estimated by eye and drawn passing through or close to the centre. Analytically this corresponds to transforming to Cartesian coordinates and estimating a linear least-squares fit. The clinician determines, from the angular displacement of this line, the colour anomaly of the subject and, from the summation of the 85 error scores, the severity of the anomaly.

AUTOMATION OF THE FARNSWORTH-MUNSELL 100-HUE TEST

Although the 100-hue test is simple and rapid compared with tests of comparable sensitivity that predated it, manual scoring and plotting are tedious. This led Donaldson (3) to develop an automated instrument for data acquisition, computing and plotting. This instrument uses special caps and boxes wired to a TTL processor. Caps are electronically coded for colour value and plug into jacks spaced along each box. After the subject reorders the caps in the usual manner, the processor interrogates each jack or position in the box to determine the colour value of the cap plugged into it. The processor also controls a polar plotter driven by a stepping motor and, after computing the error scores, plots them according to Kinnear's protocol (2) for choosing the azimuthal coordinate. The polar grid for this instrument appears not to conform to Farnsworth's but rather has radial lines spaced at equal increments of 360/85°. In the reported version, this instrument does not store the data on a random access mass storage device. Also, estimating a line of best fit is still a manual task and imprecise mapping of the data introduces a slight inaccuracy.

THE "FARN" DATA MANIPULATION SYSTEM

This is a rudimentary microcomputer-based data manipulation system for 100-hue tests. The method does not include the automated data acquisition approach since only the out-of-sequence cap values and their positions have to be entered. This task may be accomplished by a skilled operator using a standard keypad in a few seconds. A "checksum" algorithm and another to test for double cap entries while the data are being entered ensure that the task is completed properly. New data are stored on diskette in a subject data file. Old records may be accessed and any error series may be drawn with precision on a Farnsworth polar grid using a digital plotter. Either the Farnsworth or Kinnear (2) protocols for choosing the azimuthal coordinate may be employed. The line of best fit may also be computed and plotted. Owing to the speed of the plotter, this system accomplishes the tasks of plotting and fitting swiftly. An algorithm eliminates time wasted in computing error series manually. Although the system is very much faster than the manual alternative, this is not the main advantage.

Since the system is attractive to the test administrator, owing to reduction of tedium and avoidance of human error, a very useful database is being created without any extra workload. Thus, the system enables us to create and maintain a database on a broad range of colour anomalies. It may also be used for data enhancement using decomposition techniques. Multiple group discriminant analysis techniques may be used to separate overlapping anomalies in population data.

Creation of the database has been in progress since June 1982. Results of current tests are routinely entered at the time of administration. Also, existing patient records of Farnsworth-Munsell data derived through identical test protocols and related to concommitant clinical studies will eventually be entered. These studies must be sufficiently broad that they delineate the probable disease entities of the patient.

In addition this system lends itself to inclusion of archival information in its database. Countless numbers of Farnsworth-Munsell test sheets on documented patients lay buried in paper based filing systems worldwide and are presently irretrievable by on-line access for computer examination. These constitute a vast source of potential clinical data awaiting further analysis.

Applications

Two contaminants present in the Farnsworth-Munsell 100-hue data are the negative and positive "box end effects". The negative effect is a consequence of two of the movable caps having the same hue as one or other of the pilot caps. Therefore the subject only has to match hues at the box ends to obtain the correct selection. The positive effect is more difficult to explain. To varying degrees, some patients exhibit increased colour confusion at the box ends. It appears that having more than one

cap in correct order on both sides of the one being placed helps the subject in finding the correct sequence. At the box ends, there is only one fixed cap on the outside, to assist in correct placement. This results in extra peaks in the polar diagram. The height of these contaminant peaks varies amongst subjects. They may range in significance. At one extreme, they may be below the mean artifact level. At the other, they will be so significant as to bias the estimate of the colour confusion axis.

The box-end-effect sequence B(i) itself may constitute useful data in assessing, for instance, the attentiveness of the subject at the time the test was administered. In this case, the colour-confusion sequence K(i) would be considered a "contaminant". It would be desirable then to separate these two components of the error-score sequence. If we assume that

$$S(i) = B(i)*K(i)$$

then, using a model $B_m(i)$ for the box end effect sequence, an estimate of the colour confusion sequence, $K_e(i)$, may be obtained by signal decomposition techniques.

Another contaminant may be introduced by the test administrator in computing the error sequence. Although the practice is strictly incorrect, some administrators include the fixed end caps in the calculation for the box end positions. The effect of this is not so decisive. In many instances it would tend to reduce the error score at the box end but there are some cap orders for which this "final cap" contaminant increases the score. This is not a problem in our system since, when new test data are entered, they, and not the computed error sequence, are stored. However, in archival records, where the original test data have been discarded and only the computed error sequence remains there will be uncertainty regarding "fixed cap" contaminant. This effect may also be removed, using a suitable model and criterion function for optimization.

Another application is simple but important. The Farnsworth polar grid has a maximum radial graduation of 14. Usually, when performing tests manually, administrators do not take the trouble to scale the error sequence data if some of the points lie outside the grid; they simply leave these points off the graph. In cases where there is a high mean level of artifact this is unsatisfactory since it is difficult for the clinician to determine the axis of colour confusion. In our system an automatic scaling algorithm comes into effect if off scale data are detected.

The "FARN" system has been developed with a view to an extended system, including other related databases. Several automated tests are being developed for visual function assessment. Being able to manipulate data from all of these tests is the possibility that motivated creation of the extended system. It is intended for use by diagnosticians and other researchers. In the long term view the extended database will offer them the potential of arriving at a new classification for disease.

System Hardware and Software

The equipment used is a common laboratory microcomputer and a digital plotter interfaced to it. The operating system is similarly ubiquitous and the configuration is standard. The program is currently implemented in the version of the BASIC language which is a key feature of the operating system.

Figure 2 shows the top-down design of the "FARM" data manipulation system. The design is remarkable simple and is organised for convenient creation and correction of subject data files. Pseudocode and flow diagrams are shown in Appendix A and source code is contained in Appendix B.

Data File Specifications

Subject data are stored in standard RT11 sequential files. These contain information in ASCII code.

Each file specifier is of the form

<filename>.<D/S>nn

where <filename> is a maximum of six alphabetic or numeric characters long, <D/S> is either D or S indicating the right or left eye, respectively, and nn is the test number which may range from 1 to 99.

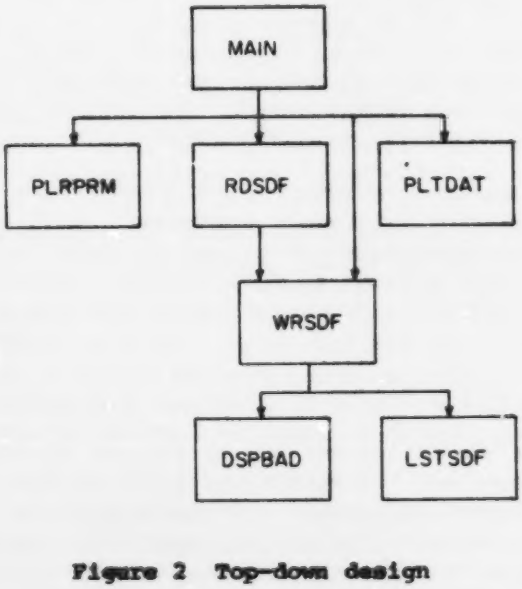

Figure 2 Top-down design

USER'S MANUAL

Beginnings

FARN is very easy to use. You will need

- a Digital Equipment Corporation MINC laboratory microcomputer with the MINC-11 BASIC operating system and
- a Hewlett-Packard HP 7225B digital plotter with the IEEE 488 option

Step 1

Connect the IEEE cable emerging from the MINC to the IEEE module in the back of the plotter. Set the listen/talk switch to listen-and-talk. Set the address switches to 5, given by the following sequence:

SWITCH #	12345
POSITION	00101 (binary) = 5 (decimal)

Check the power connections to the MINC, the terminal and the plotter. Place a System diskette in drive #0 and, if you have a FARN working diskette, insert it in drive #1. NEVER insert the FARN Master diskette in drive #1. Switch on the power to all three units. When you do this the MINC operating system will "boot up". Respond to the prompts to enter the date and time in the formats dd-mm-yy and hh:mm:ss, respectively.

Step 2

If this is your first encounter with FARN, you must create a working diskette. If you have a working diskette already, jump to Step 3. To proceed, place a new diskette, or an old one you wish to recycle, in drive #1. In response to the 'READY' prompt, type

```
DIR DY1:<ret>
```

where <ret> means the RETURN key and check the directory listing to ensure the diskette contains no files you wish to retain.

Next, enter

```
INITIALIZE DY1:<ret>
```

This initializes the directory in DY1: and although the command does not delete files on the diskette, it makes access almost impossible. Now remove the system diskette from drive #0, insert the FARN master diskette and enter

```
COPY DY0:FARN.BAS DY1:<ret>
```

Alternatively, you may enter

DUPLICATE<ret>

and respond to the ensuing prompts if you wish to duplicate all files on DYO:. This is especially useful in "backing up" files periodically for safety in case your working diskette becomes damaged. On completion, remove the FARN master and replace the system diskette in drive #0.

Step 3

In response to the 'READY' prompt, type

RUN DY1:FARN.BAS<ret>

FARN is now running.

Operating Instructions

The FARN prompt messages are self explanatory, so you may prefer continuing at the MINC terminal and referring to the flow diagrams in Appendix A instead of reading this section. The following provides a detailed description of each step, in the order in which it occurs.

1. *Plotter Set-up Instructions*

The system first displays these instructions:

```
INSERT THE DIGITISING SIGHT INTO THE PLOTTER'S PEN HOLDER.
LOAD A BLANK FARNSWORTH POLAR CHART ONTO THE PLATEN SURFACE.
USE THE CLUSTER OF ARROWS ON THE PLOTTER TO MOVE THE SIGHT.
IN YOUR NEXT 3 ACTIONS:-
       MOVE IT TO THE CENTRE OF THE FARNSWORTH POLAR CHART,
```

It is not absolutely necessary to use a digitizing sight; you may be able to manage with a plotter pen. Nevertheless, you may prefer to align the plotter carriage with the Farnsworth polar grid using the digitizing sight for greater ease and precision. When loading the chart paper, it is not necessary to align it by eye with the platen surface, since the program automatically aligns the carriage with the grid. Referring to Fig. 3, the centre of the polar chart is indicated by the label "POSN 1". When the plotter carriage is positioned to your satisfaction, strike the <ret> key. At this point, the coordinates of the carriage are transmitted to the computer and placed in memory. The next prompt is

MOVE IT TO POSITION [2, 1],

Here we are using an [r, θ] system of coordinates for brevity. Strictly this is incorrect since the radial values are offset from the origin by a

Name..... Age..... .....Date...../ ...../

85	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42
43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63
64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84

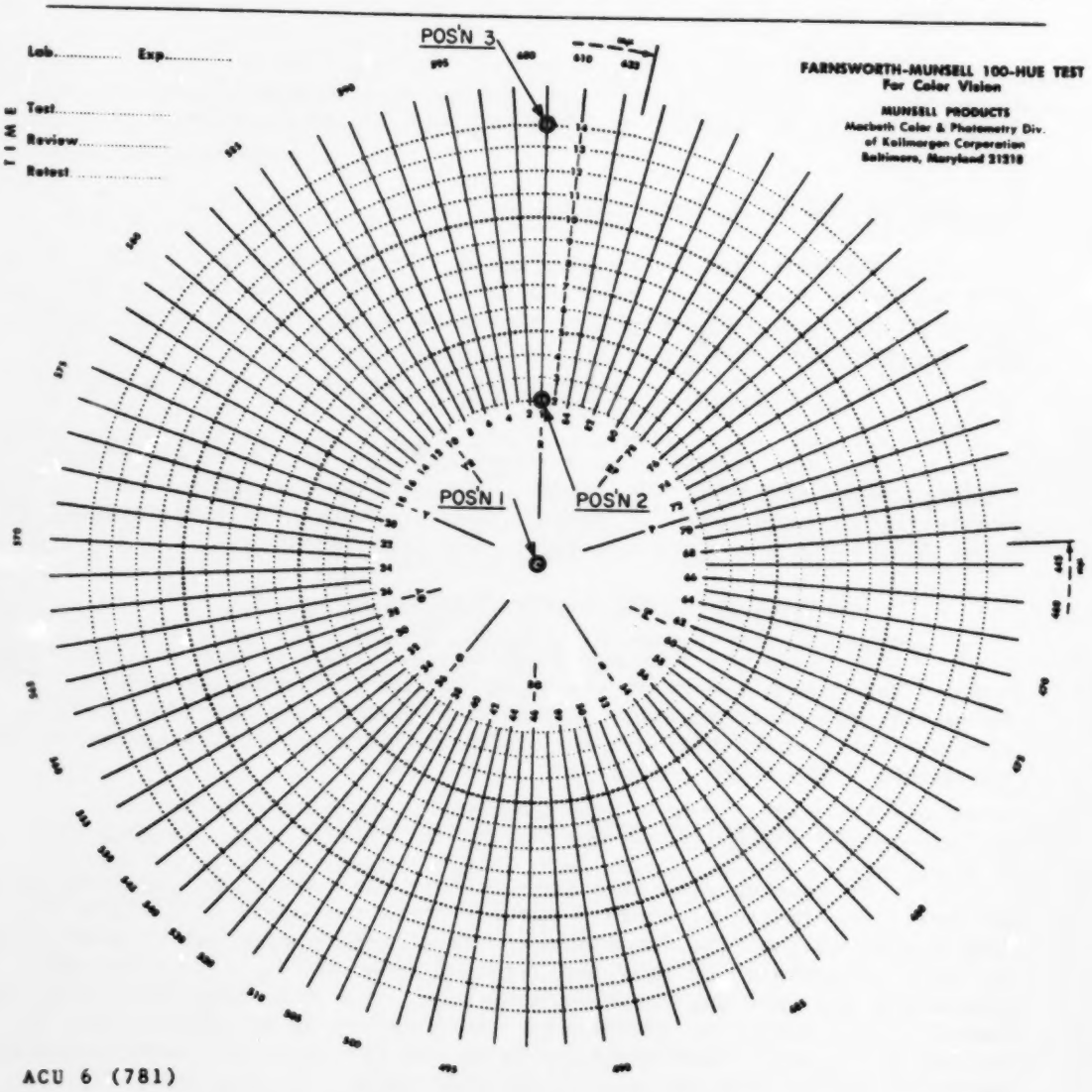

Figure 3 Positions for automatic plotter alignment

constant factor and the θ increments are not exactly of equal size, but it will suffice. The position [2, 1] is where the circle of radius 2 and the radius of angular displacement 1 intersect and is indicated in Fig. 3 by the label "POSN 2". Position the carriage as instructed and strike <ret>. The next prompt is

MOVE IT TO POSITION [14, 1].

This position is indicated by the label "POSN 3" in Fig. 3. Again strike <ret> after positioning the carriage.

NOW, if you are using a digitizing sight REPLACE IT WITH A PEN AND STRIKE THE <pen down> KEY ON THE PLOTTER.

By this time the computer will already have calculated the radial and angular offsets it will use subsequently to plot graphs and is displaying this information on the MINC terminal as a potential aid for debugging.

2. Subject Data File Identification

The next step is to identify a subject data file. Your intention may be to identify an existing file on disk for analysis or alternatively to create a new disk file. In either case the next three prompts and responses are identical:

TYPE PATIENT'S FILENAME (MAX 6 CHARS) ?

Any name may be used provided it is no more than six alphabetic and/or numeric characters in length. The patient's surname or an abbreviation may be used. A cross reference code is another alternative. Enter the filename and strike <ret>. The next prompt is

LEFT OR RIGHT EYE (<RET>/R<RET>) ?

The left eye is the default choice in which case you just strike <ret>. This makes the first character of the filename extension an "S" for sinister. Alternatively, if you wish to identify the right eye, strike R<ret>, which will set the first character of the extension to "D" for dexter. The third prompt is:

WHICH TEST #? ENTER nn(= 01 to 99)<ret> ?

Obviously, since the same patient may have to be retested several times, for instance, every 6 months, it is necessary to include the test number in the file identifier. The file extension may consist of up to three characters and only one has been used so far. The other two characters are used for the test number nn. The file identifier will now resemble, for instance, SMITHA.S03. Here SMITHA is an abbreviation for the patient's name, Anna Smith, used as the filename. S identifies tests performed on her left eye and the file contains data for test #03. WARNING: when entering new data, be careful not to use the same identi-

fier as is used for an existing disk file you wish to preserve; if you do so, the existing file will be overwritten! The final prompt is

```
INPUT NEW DATA (Y<ret>/<ret>)  ?
```

You must now specify your intention, either to input new data, in which case FARN opens a new file on the disk or, alternatively, to access an existing subject data file, in which case FARN opens this "old" file for input to FARN. Strike Y<ret> to create a new data file. The default results in the existing file being opened or a system error message if the file cannot be found.

At this point there will be further prompts which differ depending on whether a new subject data file is being created (Sect. 3) or, alternatively, if an existing file is being accessed (Sect. 4). Following these further prompts, FARN displays on the terminal 85 rows of 5 numbers. Each row is for one of the 85 possible cap positions and is intended as a potential debugging aid.

Next FARN reports the cumulative error score on the terminal

```
CUMULATIVE ERROR SCORE= nnnn
```

which, in this revision of FARN, you should record manually on the polar chart. Finally the polar diagram is plotted and on completion the MINC "READY" prompt is displayed on the terminal.

3. Entering Data into a New Subject Data File

In the 100-hue test it is necessary only to record out-of-sequence data. In-sequence data are redundant. Three operator instructions are displayed followed by prompts for data:

```
INPUT CAP NUMBERS WHICH ARE OUT OF SEQUENCE
TYPE THE SEQUENCE NUMBER FOLLOWED BY THE CAP NUMBER
TYPE N<ret> IF THERE ARE NO MORE
POSN#           CAP#
?
                ?
```

Strike <ret> after entering each number. When all the data have been entered, strike N<ret>. As data are entered, FARN checks for double entries for each cap number. If a double entry occurs a FARN error message is displayed:

```
BAD DATA. Reexamine
POSN#           CAP#
pp1             cc
pp2             cc
```

Re-enter correct values and continue:

On striking N<ret>, FARN does a checksum test on the error series to ensure that all the data have been entered. If the data file passes this test, the message

```
Passed error series CHECKSUM test/Writing SDF to disk
```

is displayed and, as indicated, the subject data file is written to the disk. If, however, it fails the test, the FARN message

```
Error series CHECKSUM deviation =      nnnn
BAD DATA. Reexamine:-
POSN#           CAP#
```

is displayed, followed by a complete listing of the incorrect data file, and the prompt

```
Re-enter correct values and continue:
POSN#           CAP#
?
                ?
```

In this event reexamine the subject data file carefully for errors and proceed to reenter the corrections as above.

4. *Access Existing Subject Data File*

On choosing to access an existing subject data file, FARN displays the caption

```
Subject's Data File contains:
POSN#           CAP#
```

followed by the contents of the file and the prompt

```
CORRECTIONS (Y<ret>/<ret>)  ?
```

This allows for the eventuality where a file has been created, having passed the double entry and checksum tests described in Sect. 3, but nevertheless contains "correct" entries in the wrong order. If you do not wish to reorder data in the file, the default response causes processing to continue. If, alternatively, you wish to correct data which are in the wrong order, strike Y<ret> and continue as in Sect. 3.

REFERENCES

1 Farnsworth, D. J. Opt. Soc. Am. 33: 568; 1943.

2 Kinnear, P.R. Vision Res. 10: 423; 1970.

3 Donaldson, G.B. Instrumentation for the Farnsworth-Munsell 100-hue test. J. Opt. Soc. Am. 67(2): 248-249; 1977.

APPENDIX A

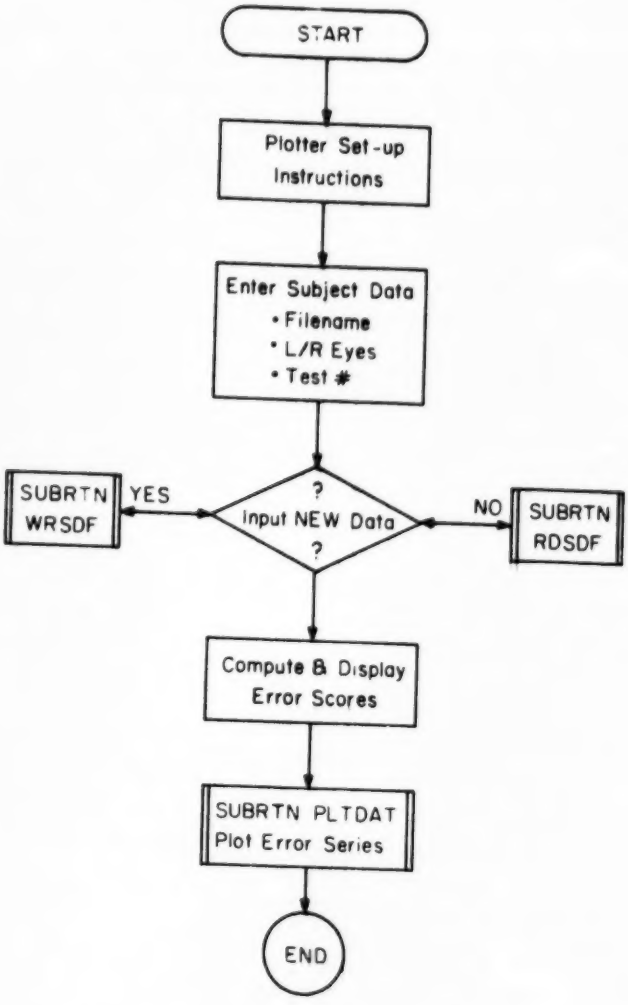

Figure A1 FARM, the main program

Main Program, FARN Pseudocode

```
*       START
*       Open file 'DY0:BOX***.DIR' as a virtual file, channel#1
*       Dimension channel#1 virtual array B$(4), string length=10
*       If B$(0) ='**********' then
*           Begin
*           CALL SDFIDN to identify SDFname/ LorR eye/ test#
*           Does operator want to enter new data?
*           If yes then
*               Begin
*               B$(0)= SDF name/ written to DY0:BOX***.DIR
*               CALL subroutine WRSDF
*               End
*               Else    CALL subroutine RDSDF
*           End
*           Else
*           Begin
*AAA        Display BS(0) is the current SDF being created
*           Select  continue                        (<ret>) or
1                   initialise   'BOX***.DIR'   and   commence
2                       entering data for new test (I<ret>)?
*           Input new Z$ from keyboard
*           If Z$='I' then
*               Begin
*               CALL SDFIDN to identify SDFname/ LorR eye/ test#
*               B$(0)=<SDFname>
*               For J=1 TO 4
*                   B$(J)='**********'
*               Next J
*               End
*               Else
*               If Z$not='' then GO TO AAA
*           CALL subroutine WRSDF
*           End
*       Display plotter setup instructions
*       Compute and display error scores
*       CALL PLTDAT
*END    END
```

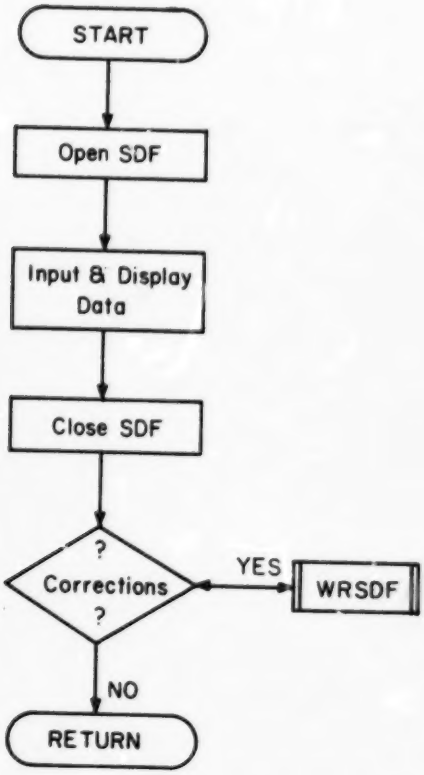

Figure A2 Subroutine RDSDF

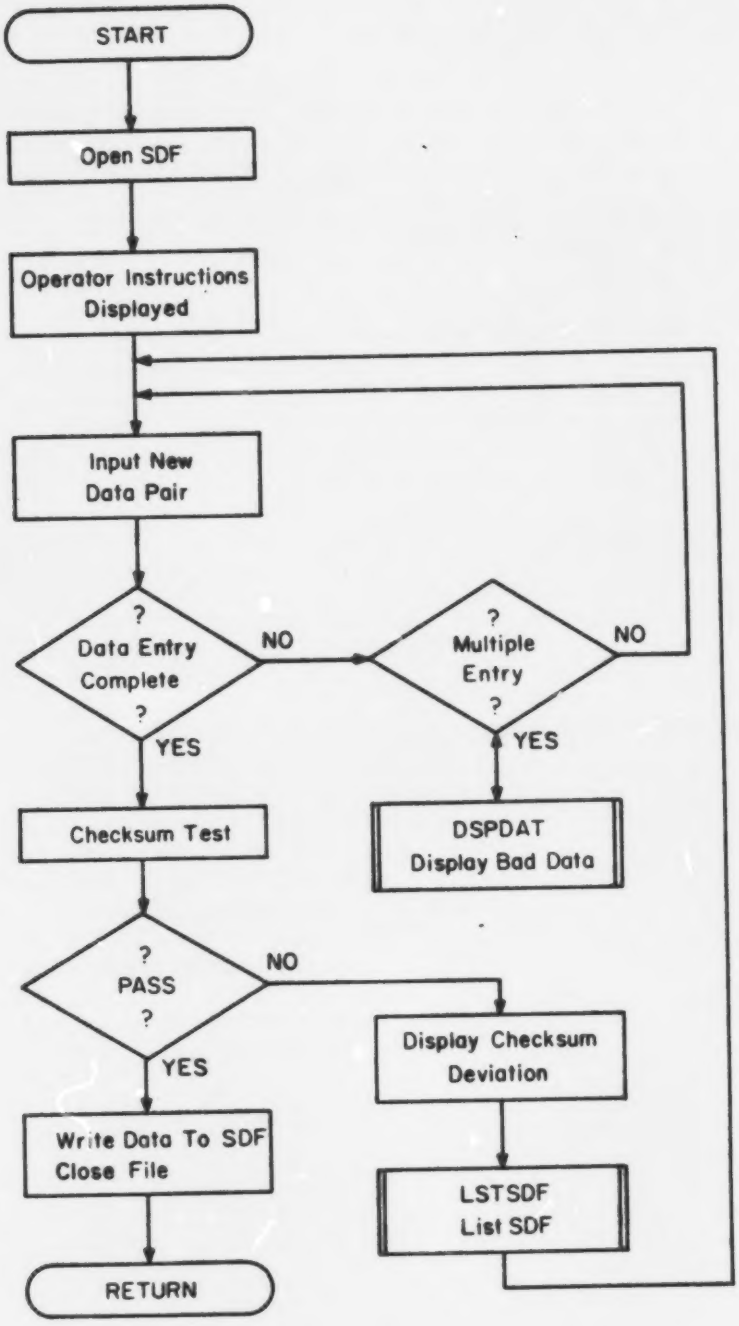

Figure A3 Subroutine WRSDF

Subroutine WRSDF Pseudocode

```
Comments:- writes data to subject data file

*       Set up box end table, B(4,2)%
*       Set up checksum table, C(4)%
*       Initialise string B1$='BOX'
*       For I=1 to 4
*           Begin
*           B1$=B1$+'<I>'+'**.DAT'
*           If B1$=B$(I) then
*               GO TO AAA
*               Else
*               If B$(I) not='**********' then
*                   Begin
*                   Display 'Warning, B$(I)=',B$(I)
*FFF                Select      Stop    (S<ret>) or
1                               Continue (<ret>)?
*                   If Z$not='s' then if Z$not='' go to FFF
*                   If Z$='S' then
*                       GO TO END
*                   End
*           Display - B1$ data is missing for subject B$(0)
*BBB        Select  enter B1$ data (E<ret>) OR
1                   skip to next box check (<ret>)?
*           Input Z$ from keyboard
*           If Z$not='E' then if Z$not='' go to BBB
*           If Z$='E' then
*               Begin
*               OPEN B1$ as a sequential file on channel#2
*               display operator instructions
*CCC            Input new box position number or 'N' no more data
*               If Z$not='N' then if val(Z$) not in range 0 to 84
*                   go to CCC
*               If Z$='N' then
*                   Begin
*                   Checksum test
*                   If checksum test passed then
*                       Begin
*                       write data to file BOX<I>**.DAT
*                       Close file
*                       B$(I)='BOX<I>**.DAT'
1                            -written in DY0:BOX***.DIR
*DDD                    Select Quit data entry session (Q<ret>) OR
1                             Continue with next box  (<ret>)?
*                       Input new Z$ from Keyboard
*                       If Z$not='Q' then if Z$not='' go to DDD
*                       If Z$='Q' then GO TO END
*                       End
*                       Else
*                       Begin
```

```
*                       display checksum error deviation
*                       list current box, B1$, data file
*                       GO TO CCC
*                       End
*                   End
*                   Else
*                   If posn# is within range of current box then
*                       Begin
*                       ENTER CAP # AND CHECK RANGE
*                       Multiple entry test
*                       If multiple entry then
*                           Begin
*                           CALL DSPBAD
*                           GO TO CCC
*                           End
*                       End
*                       Else ( its outside range )
*                       Begin
*                       Display 'data outside range of box B$(I)'
*EEE                    Select  skip to next box check (S<ret>) or
1                                   Try again                (<ret>)?
*                       Input Z$ from keyboard
*                       If Z$not='S' then if Z$not='' go to EEE
*                       If Z$='S' then
*                           GO TO AAA
*                           Else
*                           GO TO CCC
*                       End
*               End
*           End
*AAA    Next I
*      Test if all 4 box data sets are filed?
*      If YES then
*          Begin
*          Open B$(0) as SDF on channel#3
*          For I=1 to 4
*              Begin
*              Open DY0:BOX<I>**.DAT ON CHANNEL#2
*              Concatenate DY0:BOX<I>**.DAT into SDF
*              close channel#2
*              End
*          Next I
*          Close channel#3
*          For I=1 to 4
*              Kill DY0:BOX<I>**.DAT
*          Next I
*          For I=0 to 4
*              B$(I)='**********'
*          Next I
*          End
*          Else
*          GO TO END
*      RETURN
```

APPENDIX B

Main Program

```
10 IEEE_BUS_CLEAR
20 DIM M%(3,3)
30 DIM D%(2,2)
40 DIM M$(20)
50 DIM P%(3)
60 DIM T%(84),S%(84),C%(84)
70 LET M$(1)=' MOVE IT TO THE CENTRE OF THE FARNSWORTH POLAR CHART'
80 LET M$(2)=' MOVE IT TO POSITION [2,1]'
90 LET M$(3)=' MOVE IT TO POSITION [14,1]'
100 M$(11)='    BAD DATA. Reexamine:-'
110 M$(12)='    POSN#              CAP#'
120 M$(13)='    Re-enter correct values and continue:-'
130 PRINT "INSERT THE DIGITISING SIGHT INTO THE PLOTTER'S PEN HOLDER"
140 PRINT "LOAD A BLANK FARNSWORTH POLAR CHART ONTO THE PLATEN SURFACE"
150 PRINT "USE THE CLUSTER OF ARROWS ON THE PLOTTER TO MOVE THE SIGHT"
160 PRINT "IN YOUR NEXT 3 ACTIONS:-"
170 FOR I=1 TO 3
180 PRINT M$(I); \ INPUT Z$
190 GOSUB 1030
200 NEXT I
210 REM ************************************************************
220 REM COMPUTE OFFSETS IN FARNSWORTH UNITS, RADIAL (O)AND
230 REM ANGULAR (T)
240 REM ************************************************************
250 D%(1,1)=M%(2,1)-M%(1,1)
260 D%(1,2)=M%(2,2)-M%(1,2)
270 O=SQR(D%(1,1)^2+D%(1,2)^2)
280 LET O1=SQR((M%(3,1)-M%(2,1))^2+(M%(3,2)-M%(2,2))^2)
290 IF O1<>0 THEN  GO TO 330
300 REM ******************** START OVER ***************************
310 PRINT 'MOVE THE SIGHT WHEN YOU ARE TOLD TO'
320 GO TO 150
330 LET O1=O1/12
340 O=O/O1-2
350 PRINT 'RADIAL OFFSET=',O
360 X=D%(1,2)
370 X=X/D%(1,1)
380 PRINT 'TAN(ANGULAR OFFSET)=',X
390 T=ATN(X)
    IF D%(1,1)<0 THEN T=PI+T
    IF X<0 THEN T=2*PI-T
400 T1=2*PI/85
410 T=T/T1-1
420 PRINT 'ANGULAR OFFSET=',T
430 REM ********* GET TEST DATA ***************************
```

```
440 T%(0)=85
450 FOR I=1 TO 84
460 T%(I)=I
470 NEXT I
480 PRINT '    TYPE PATIENT"S FILENAME (MAX 6 CHARS)'; \ INPUT Z$
490 Z$='DY1:'+Z$
500 PRINT '    LEFT OR RIGHT EYE (<RET>/R<RET>)'; \ INPUT Z1$
510 IF Z1$='' THEN Z$=Z$+'.S'
520 IF Z1$='R' THEN Z$=Z$+'.D'
530 PRINT '    WHICH TEST #? ENTER nn(=01 to 99)<ret>'; \ INPUT Z1$
540 IF LEN(Z1$)<>2 THEN  GO TO 530
550 Z$=Z$+Z1$
560 PRINT Z$
570 PRINT '    INPUT NEW DATA (Y<CR>/<CR>)'; \ INPUT Z1$
580 IF Z1$='' THEN  GOSUB 1540
590 IF Z1$='' THEN  GO TO 630
600 IF Z1$='Y' THEN  GOSUB 1190
610 IF Z1$='Y' THEN  GO TO 630
620 GO TO 570
630 FOR I=0 TO 84
640 IF T%(I)<128 THEN  GO TO 660
650 T%(I)=T%(I)-128
660 NEXT I
670 REM ********* GET ERROR SCORES **********************
680 FOR I=0 TO 21
690 IF T%(I)=85 THEN T%(I)=0
700 NEXT I
710 S%(0)=ABS(T%(0)-T%(84)+85)+ABS(T%(1)-T%(0))
720 PRINT '85',S%(0),(T%(84)-85),T%(0),T%(1)
730 FOR I=1 TO 83
740 S%(I)=ABS(T%(I)-T%(I-1))+ABS(T%(I+1)-T%(I))
750 PRINT I,S%(I),T%(I-1),T%(I),T%(I+1)
760 NEXT I
770 S%(84)=ABS(T%(84)-T%(83))+ABS(T%(0)+85-T%(84))
780 PRINT '84',S%(84),T%(83),T%(84),(T%(0)+85)
    REM ******* CUMULATIVE ERROR SCORE ************************
    C0=0
    FOR I=0 TO 84
    C0=C0+S%(I)
    NEXT I
    C0=C0-170 \ REM Subtract 85x( the error score offset, 2 )
    PRINT 'CUMULATIVE ERROR SCORE=',C0
790 REM ************** PLOT ERROR SCORES ***********************
800 FOR I=0 TO 84
810 F=(I+T)*T1
820 S1%=S%(I)
830 IF S%(I)>14 THEN S1%=16
840 R=(S1%+O)*O1
850 GOSUB 940
```

```
860 NEXT I
870 F=T*T1
880 R=(S%(0)+O)*O1
890 GOSUB 940
900 GO TO 1890 \ REM GO TO END
1890 END
```

Subroutine PLRPRM

```
990 REM ************************************************************************
1000 REM SUBROUTINE READS PLOTTER'S CARRIAGE COORDINATES AND STATUS
1010 REM AND RETURNS THEM IN ARRAY M%(I,J)USING OA;
1020 REM ************************************************************************
1030 A$='' \ REM DUMMY LINE
1040 SEND("OA;",5)
1050 RECEIVE(A$,,5)
1060 IF SEG$(A$,1,1)=' ' THEN A$=SEG$(A$,2,LEN(A$))
1070 P%(0)=0
1080 FOR J=1 TO 3
1090 P%(J)=POS(A$,',',P%(J-1)+1)
1100 IF P%(J)=0 THEN P%(J)=LEN(A$)+1
1110 M%(I,J)=VAL(SEG$(A$,P%(J-1)+1,P%(J)-1))
1120 NEXT J
1130 PRINT A$
1140 PRINT M%(I,1),M%(I,2),M%(I,3)
1150 RETURN
```

Subroutine RDSDF

```
1510 REM ************************************************************************
1520 REM ********** SUBROUTINE READS PATIENT'S FILE **************
1530 REM ************************************************************************
1540 OPEN Z$ FOR INPUT AS FILE #1
1550 PRINT "    Subject's Data File contains:-"
1560 PRINT M$(12)
1570 IF END #1 GO TO 1630
1580 INPUT #1,I$,T$
1590 I=VAL(I$)
1600 T%(I)=VAL(T$)
1610 PRINT '    ',I,'    ',(T%(I)-128)
1620 GO TO 1570
1630 CLOSE #1
1640 PRINT '    CORRECTIONS (Y<CR>/<CR>)'; \ INPUT Z2$
1650 IF Z2$='Y' THEN  GOSUB 1190
1660 RETURN
```

Subroutine WRSDF

```
1160 REM ************************************************************
1170 REM SUBROUTINE WRITES TO PATIENT DATA FILE
1180 REM ************************************************************
1190 OPEN Z$ FOR OUTPUT AS FILE #1
1200 PRINT '    INPUT CAP NUMBERS WHICH ARE OUT OF SEQUENCE'
1210 PRINT '    TYPE THE SEQUENCE NUMBER FOLLOWED BY THE CAP NUMBER'
1220 PRINT '    TYPE N<CR> IF THERE ARE NO MORE'
1230 PRINT M$(12)
1240 PRINT '    '; \ INPUT Z$
1250 IF Z$<>'N' THEN  GO TO 1400
1260 J=0
1270 FOR I=0 TO 84 \ J1=T%(I) \ IF J1>128 THEN J1=J1-128
1280 J=J+J1
1290 NEXT I
1300 IF J=3655 THEN  GO TO 1330
1310 PRINT '    Error series checksum deviation =',(J-3655)
1320 GOSUB 1810 \ GO TO 1230
1330 PRINT '    Passed error series CHECKSUM test/Writing SDF to disk'
1340 FOR I=0 TO 84
1350 IF T%(I)<128 THEN  GO TO 1370
1360 PRINT #1,STR$(I);',';STR$(T%(I))
1370 NEXT I
1380 CLOSE #1
1390 RETURN
1400 I=VAL(Z$)
1410 IF I=85 THEN I=0
1420 PRINT '                    '; \ INPUT T%(I)
1430 I1=T%(I)
1440 T%(I)=T%(I)+128 \ REM **** USE BIT#7 FOR PRINT FLAG
1450 FOR J=0 TO 84
1460 IF J=I THEN  GO TO 1490
1470 J1=T%(J) \ IF J1>128 THEN J1=J1-128
1480 IF J1=I1 THEN  GOSUB 1710
1490 NEXT J
1500 GO TO 1240
```

Subroutine PLTDAT

```
910 REM ************************************************************
920 REM SUBROUTINE TO PLOT DATA IN POLAR COORDINATES
930 REM ************************************************************
940 X%=COS(F)*R+M%(1,1)
950 Y%=SIN(F)*R+M%(1,2)
960 M1$='PA'+STR$(X%)+','+STR$(Y%)+';'
970 SEND(M1$,5)
980 RETURN
```

Subroutine DSPBAD

```
1670 REM ************************************************************************
1680 REM ************* SUBROUTINE DISPLAYS BAD DATA *****************
1690 REM ************* INPUT PARAMETERS J,J1,I,I1 *******************
1700 REM ************************************************************************
1710 PRINT M$(11)
1720 PRINT M$(12)
1730 PRINT '    ',J,'    ',J1
1740 I2=I \ IF I=0 THEN I2=85
1750 PRINT '    ',I2,'   ',I1
1760 PRINT M$(13)
1770 RETURN
```

Subroutine LSTSDF

```
1780 REM ************************************************************************
1790 REM ********* SUBROUTINE LISTS SDF *****************************
1800 REM ************************************************************************
1810 PRINT M$(11)
1820 PRINT M$(12)
1830 FOR J=0 TO 84
1840 IF T%(J)<128 THEN  GO TO 1860
1850 PRINT '    ',J,'    ',(T%(J)-128)
1860 NEXT J
1870 PRINT M$(13)
1880 RETURN
```